Epistemic Justification and Luck in Inflationary Cosmology

By: Casey McCoy

In this paper I present a recent case in theoretical cosmology, and argue on its basis that explanatory considerations can play a crucial role in epistemically justifying theory choice. Much of the philosophical debate over whether explanatory power is an epistemic theoretical virtue has centered on general philosophical considerations, for example underdetermination arguments and whether inference to the best explanation (IBE) is a generically valid form of reasoning (especially for its applicability to the scientific realism debate). Attending to the specific roles that explanation plays in scientific methodology, especially the way it structures discourse in a discipline and coordinates exemplars, reveals the possibility of justifying explanatory power as an epistemic virtue in specific scientific cases, without reliance on general philosophical arguments based on IBE or underdetermination. This kind of argument naturally requires close attention to the historical development of a theory and its applications.

Inflationary cosmology, I claim, offers just such a compelling, concrete example. Inflation is a cosmological scenario that was originally proposed in the early 1980s by Alan Guth. It was widely accepted in the community immediately after its introduction, and remains a central pillar of the contemporary standard model of cosmology, the ?CDM model. Inflationary theory is based on the supposition that the very early universe underwent a brief period of accelerated and exponential spatial expansion. Proponents claim that the effect of inflation is to flatten the spatial geometry of the universe and make its contents more uniform. (One may usefully compare it to the inflation of a balloon, which decreases the curvature of the balloon's surface and smooths small irregularities.) This mechanism is thought to operate for a short period in the very early universe, giving rise to the conditions that eventuate in the present spatial flatness and uniformity, conditions which we infer today from observations of the cosmic microwave
background (CMB) radiation. Proponents also claim that the old standard cosmological model, the well-known hot big bang (HBB) model, suffers from fine-tuning problems. Earman and Mostern have emphasized that these fine-tuning problems are not problems concerning the HBB model's consistency or empirical adequacy, since the model is capable of explaining the present flatness and uniformity of the universe; rather the problems appear to raise concerns over the kind of explanation given by the model for certain physical features of the universe which are accessible to observation. In particular, only explanatorily-definicient special initial conditions can give rise to these presently- observed conditions within the context of the HBB model. Since uniformity and flatness are thought to be natural outcomes of inflation, the previous paradigm's fine-tuning problems are apparently solved by inflationary theory, thus leading to the claim that inflationary models represent real theoretical progress over the HBB model.

Although inflation was widely accepted ostensibly on the basis of such fine-tuning arguments during inflationary theory's early history, at present the best argument for inflationary theory is not that it (allegedly) solves these problems; instead it rests on the striking empirical confirmation in the 90s of quantum mechanical predictions developed out of the inflationary framework, specifically of a very precise spectrum of anisotropies of the cosmic microwave background (CMB). If this latter, empirical argument is successful and it at least appears to be taken as such by most contemporary cosmologists then inflationary theory should reasonably be considered an empirically successful theory whose predictive successes go beyond the HBB model, and therefore represent progress over it. Yet it is

important to note that these predictions were unforeseen at the time of inflation's proposal and initial acceptance. How then is it, that a theory, seemingly unjustified on any of the commonly accepted epistemic grounds, should later find itself strikingly confirmed observationally? The case appears to be one of extraordinary epistemic luck, roughly, epistemic success achieved through a method no more effective than guessing. Yet supposing it so is quite implausible, for epistemic luck in the confirmation of central scientific theories would severely threaten intuitive notions of scientific progress and rationality. The alternative to such skepticism is to consider that inflation's rapid and early acceptance among cosmologists was somehow epistemically justified prior to any observational support, and on grounds other than observational support or solving theoretical inadequacies in the Standard Model. Therefore the case of inflation shows us that a view of epistemic justification based solely on the simple and familiar criteria of empirical adequacy and theoretical consistency (in particular as employed by Earman and Mostern in their assessment of inflation) is inadequate.

I claim that the epistemic justification of inflationary theory (before its observational confirmation) rests instead crucially on explanatory considerations, considerations which may be seen to arise from its approach to solving the HBB model's fine-tuning problems and explaining presently observed cosmological conditions. One might wonder, "How can solving such mere explanatory problems represent progress towards an empirically successful theory?" Insofar as scientific progress may be gauged by solving scientific problems (la Kuhn or Laudan), one has, I claim, an explanatory story linking inflationary theory's putative success at solving the HBB model's fine-tuning problems with the later confirmation of its observational predictions. Roughly speaking, one might say that by solving the HBB model's conceptual problems, inflationary theory proves itself to be a progressive research program suitable for further development and empirical test. This viability depends on a certain kind of "meta-empirical" confirmation. Although, certainly, there is no guarantee that its predictions will be borne out, one's confidence in the theory is justified by its past problem-solving success. The viability of some such story of course depends however on whether inflation does in fact solve the HBB model's fine-tuning problems in some sense, but this argument sketch makes considerably more sense of the historical development of inflationary theory than an impoverished view of empirical justification in science can.